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EAST AFRICAN GEODETIC NETWORKS - WHAT NEXT?

B.E. FURNISTON, DIRECTOR OF OVERSEAS SURVEYS
ORDNANCE SURVEY OF GREAT BRITAIN, UNITED KINGDOM

East African Geodetic Networks - What Next?

J.L. DENSHAM, Director of Overseas Surveys
Ordnance Survey of Great Britain, United Kingdom

1. The African Doppler Survey (ADOS) has received wide support from African and donor nations and there are now a considerable number of stations in the Continent with coordinates derived from Precise Ephemeris Transit satellite fixations.

2. At the 3rd Symposium on Geodesy in Africa, held in April 1986 in Yamassoukro, several papers turned attention beyond the ADOS campaign itself to the development of a datum and figure of the earth which may fit the geoid in Africa more closely than those currently in use, and to the possibility of carrying out a readjustment of the existing geodetic data to provide a homogeneous, and more accurate, set of coordinated data for existing stations of national frameworks.

CURRENT ADJUSTED VALUES

3. The British Directorate of Overseas Surveys (DOS) was responsible for a great deal of the observation, and adjustment, of the geodetic framework of East and Central Africa. No comprehensive report of the field operations was produced but details of progress are contained in DOS Annual Reports. A paper setting out the sequence of adjustments and their results was presented to the Symposium 'Geodesy in Africa' held in Khartoum in 1974(1). No major adjustments of data concerning East or Central Africa have been carried out by DOS or, it is believed, by any other organisation since that time.

4. The African adjustments of DOS are certainly capable of improvement. Windsor's paper points out some of the constraints and comments:-

"Were these adjustments to be undertaken today (i.e.1974) with the large electronic computers available, they would be done very differently. The results overall would be better, particularly if the secondary breakdowns between the main networks were included in the overall adjustment".(1)

The major constraint, which was particularly severe in the earliest work, was the sheer volume of time consuming effort in large adjustments which forced work to be broken down into stages. It is difficult now to recall, or to imagine, the application and determination necessary to compute, with a hand operated mechanical calculator, the long strings of cross-multiplications necessary to enter correctly each figure in a desk sized matrix of squared paper. There were often four or more computers working round one such sheet and there was certainly no question of repeating trial solutions in search of an optimum solution. Even after electronic computers were in use the limited memory and processing speed of those available to DOS in the 1960's still limited the size and complexity of a block of observations and the vulnerability of their tape readers sometimes led to the repetition of many hours of work.

. The result, of course, was the sequential adjustment of chains of riangulation (later incorporating tellurometer traverse). After working hrough the 30th Arc, Uganda, Kenya and Northern Tanzania "preliminary work on he remaining networks in Tanzania showed that they were not going to fit very omfortably into the space that had been left for them"(1). This was disappointing ut not, in hindsight, too surprising. Large modern adjustments of complex etworks have given us all new knowledge into the ways in which errors accumulate n survey networks.

. Several studies have been made of the DOS adjustments, notably those relating o Tanzania. Most agree, in broad terms, that better values should result from large simultaneous adjustment, but no concrete steps have been made to that nd. A recent paper presented to the 3rd Symposium on Geodesy in Africa, Yanoussoukro arries criticism a good deal further, claiming "possible bad field observations, rroneous reductions and even inadequate adjustment model(s)"(2). Although the tatistical tests set out apply fully only to very large samples (and the smallest ndividual adjustment "tested" contains as few as 17 observations) the calculations t their face value simply confirm the analysis set out for each adjustment 12 ears ago(1). This is hardly surprising since the data is exactly that from indsor's paper. Readers of (2) should beware of what appears to be confusion etween corrections to observed quantities and misclosures.

. Windsor explains that all the later adjustments for which details are iven in her paper were completed by variation of coordinates with previously ixed points held as known. Thus both the corrections to measured observations nd the standard errors include the effects of any distortions caused by this rocedure. As we know, those distortions became noticeable in the Tanzania djustments and undoubtedly increased both over values which might have been ttained in a 'free' adjustment. With the tools of the day and the time which ould reasonably be allotted there was no other possibility.

. It is worth noting that the role of DOS, even when it was first created n 1946, was to produce topographic maps, primarily to identify development otential and to support the implementation of development projects. It is ntirely due to be foresight of Brigadier Martin Hotine, DOS's first Director, hat the establishment of a geodetic framework was accepted as a prerequisite to dequate, homogeneous mapping and due to his persuasive argument that funds were llotted for this purpose. Although the currently accepted DOS adjusted values ay be deficient for modern scientific purposes, the work has been adequate and s still adequate as a control framework for homogeneous mapping throughout the ommonwealth countries of East and Central Africa. It has also proved satisfactory, lthough in some parts calling for an appreciation of scale by field surveyors, s a framework for cadastral surveyors in the same countries.

The scale and orientation errors are, after all, matched by hose in the framework of many countries including Great Britain where the scale rror of the accepted values (OS GB 36) for all but the most accurate scientific urposes is some 1:20,000 in places.

OWARDS A NEW ADJUSTMENT?

. With the Doppler derived positions of ADOS stations available the opportunity or the computation of significantly more accurate values for the stations of he survey framework certainly exists. It would be a retrograde step, however, f the homogeneity of current mapping coordinates were to be damaged and it eems highly unlikely that the conversion of the awesome volume of minor survey

networks and cadastral values could be justified. The better course would be to aim for a set of scientific values. This has proved a satisfactory solution in Europe. Ordnance Survey adjustments of the British network (OSSN70 and OSSN80) have improved scale errors to something approaching part per million and the values obtained from these adjustments have been used where great accuracy is needed and for projects such as the provision of internationally agreed values for North Sea oil installations. The European ED50 datum was computed in blocks, the periphery of each block being used to control the next. Recent readjustments show significant changes to previously accepted values in Portugal, Spain, Northern Norway and Italy due to the nature of the earlier computations which passed systematic errors into the outlying countries. National mapping in Europe is, however, still usually based on the old datums and may well remain so.

10. No one should, however, underestimate the amount of work and the very considerable cost of a new homogeneous adjustment of even those frameworks established by DOS, let alone those of the whole of Africa. With modern computing technology it is not now the computation of a series of very large adjustments which is the major problem. There are, however, very large quantities of data involved all of which will require analysis, collation and checking. Although not an exciting task, the ultimate value of the whole work will depend on the pains taken at this stage.

11. In addition to the ADOS satellite fixations and the geodetic or primary chains, networks and traverses, there is a considerable quantity of high quality secondary work providing cross connections. They often contain more EDM measurements than the geodetic or primary simply because the work was undertaken later, after EDM came into general use. There can be little doubt that inclusion of selected secondary networks would add greatly to the strength of a new adjustment.

12. To incorporate the differing types and quality of observations will mean developing suitable weights. To evaluate the quality of DOS observations for this purpose, it is suggested that trial adjustments should be made of chains and/or traverse between Doppler stations, especially in Tanzania. It is only by some such means that the quality of the observations can be separated from the bias effect of positional closure on previously fixed stations.

13. Although readjustment of African survey networks would be a major task, comparable with the North American and European re-adjustments, the technical concepts and the computer power do exist. It is no light task - European nations are still working on an adjustment which started thirty years ago - and will involve considerable cost. In considering justification two points cannot be ignored.

SOS - SAVE THE OLD STATIONS

14. There must be a very real concern that too many of the old stations of the survey framework have been lost. In recent years DOS and OSD survey parties engaged on mapping projects have encountered evidence of increasing damage, and destruction of, both pillars and ground stations.

15. In North East Tanzania, between June 1983 and April 1984, in the course of reconnaissance for the establishment of ground control for 1:50,000 mapping 82 trigs were visited.

NORTH EAST TANZANIA: JUNE 83 TO APRIL 84			TOTAL DESTROYED OR AT RISK
TRIGS VISITED	BADLY DAMAGED BUT POSSIBLY RECOVERABLE	DESTROYED AND BEYOND RECOVERY	
82	16 or 19.5%	18 or 22.0%	41.5%

Over one fifth were totally destroyed and beyond recovery of any accurate position (it was sometimes possible to use the position, estimated to a metre or so, for 1:50,000 mapping purposes only). Nearly another fifth were badly damaged or missing but could, if action is taken quickly, be rebuilt accurately in their former position from buried and/or witness marks.

16. In Kenya, in July 1985, in the course of a 10 day reconnaissance for the establishment and identification of control for the air triangulation of a block of photography 41 trigs. were visited. Nearly 30% were destroyed; over half of the total were badly damaged, destroyed or missing although these could probably be rebuilt, accurately if witness marks still exist, sometimes to within a few centimetres even if witness marks are destroyed because of their particular state.

KENYA: SOUTH NYANZA: JULY 1985			TOTAL DESTROYED OR AT RISK
TRIGS VISITED	BADLY DAMAGED BUT POSSIBLY RECOVERABLE	DESTROYED AND BEYOND RECOVERY	
41	21 or 51.2%	12 or 29.5%	80.7%

17. In Uganda, OSD has no concrete statistics but have been told that a great number of survey stations of all classifications have been destroyed. It is understood that help is being sought for their replacement.

18. Most of this loss has been caused by deliberate action although this may have been based on innocent misinterpretation and/or ignorance of the function of thestations. Considerable labour and ingenuity has been used to ensure that hidden, as well as surface, marks have been destroyed. In one instance a large hole 10 metres deep had been excavated in which the remains of a 1.2 metre concrete pillar now lie.

19. There can be little point in devoting considerable time and money to the production of accurate readjusted values for survey stations which do not exist and cannot be recovered. If ground stations are important action does seem to be necessary to inform governments and people that survey stations are valuable items for infra structure, that they are costly to emplace and to coordinate and that their destruction inevitably leads to the repetition of expensive work. Government needs to be convinced of this because the only way to repair damage before it becomes terminal is to inspect stations regularly and because such regular inspection is also the best way to ensure that people generally are aware of the value placed on the concrete blocks and the way in which they are used. Funds invested in this way are, however, a very small proportion of the cost of repeating a major framework survey. General publicity, for example through schools, party offices, local councils and the offices of central government must reach ordinary people especially those living near survey framework stations, if they are to understand their function and help their preservation.

A SATELLITE FRAMEWORK

20. The past decade or so has seen enormous advances in the satellites, the techniques and the equipment for the establishment of position on the ground from the broadcast signals from satellites in space. The Transit system, via Doppler methods, is in routine use for the fixation of stations to an accuracy of a metre or two; accuracies of a few centimetres are claimed using more refined techniques and greater time.

Even though the deployment of the full satellite constellation will now be delayed because of the Shuttle accident, GPS is already in use for fixation and a new galaxy of receivers using several techniques is available and will be refined. The concept of a small package from which coordinates may be read instantaneously and refined, if necessary, by later recalculation of recorded data, is no longer a science fiction dream but near reality even if its size is not yet that of a wrist watch.

21. Before embarking on large programmes of readjustment, or of re-observation it has now become necessary to ask whether accurately coordinated ground stations are any longer required at all. This question does pose particular problems to developing countries. It may not, yet, be wholly answerable but it certainly deserves debate in this forum. A number of issues are involved - only three will be considered in this paper.

Accuracy

22. Already Doppler fixes from the Transit system are adequate for mapping controls at small scales and up to the order of 1:10,000 scale. It is certainly foreseeable that satellite fixation will be adequate for all mapping accuracies up to 1:2,500 or even 1:1250. If there is a problem at present it mainly concerns speed of fixation and a full GPS constellation may well resolve it in future.

23. Cadastral surveys have traditionally concentrated on the depiction and description of shape and relative distance rather than co-ordinates, or position. As a result it has often been held that no system of measurement which cannot reproduce the observation and calculation of orientation to something of the order of 10 seconds of arc and distance correct to something if the order of 1:1000, regardless of the length of the line concerned, can be acceptable. Sheer

expediency - the practicality of extending cadastral survey to new large areas with limited funds and limited skilled manpower, has modified these views and photogrammetry (which provides positions) has become an accepted technique. Eventually it may be that satellite fixation, especially if accuracies of a few centimetres can be achieved will provide an accuracy which is accepted. Observations (or perhaps 'readings' might be a better term since the surveyor/recorder will have little to do with the received signals!) will, however, have to be obtained quickly if efficiency is to match that of conventional techniques applied to a dense set of measurements within a small area.

24. Much the same considerations apply to many types of normal engineering survey. The setting out of roads and building sites may well become feasible with satellite fixes. In this field, however, it is likely that there will always be some special types of work where the accuracies of linear and angular measurement once associated with geodetic framework survey will be needed.

Availability

25. A question which must be of concern is whether all of us, as surveyors and providers of land information to our countries, can afford to rely on a single system, lodged in space, which might conceivably be interrupted. Space is a hostile environment and many calls on the surveyor for information may not be able to stand by if there is even a short hiatus in satellite signals, for whatever cause.

26. The beacons of the existing survey framework will remain unless they are deliberately destroyed - not generally either a practical or a sensible possibility. They should be maintained, for the cost of doing so is not great. There will, of course, always be a multiplicity of detail with mapping accuracy, cadastral beacons and other physical markers of surveyed positions. Countries will need to decide, however, whether to extend framework surveys, whether to replace missing sections and, particularly in the present context, whether to upgrade coordinate values.

Affordability

27. At present, at least, the trend is that high technology instruments (and that would include satellite fixation equipment) are cost effective provided that they are utilised intensively. They are, however, relatively expensive to purchase and their use is often dependent on highly educated and skilled manpower. The manpower is limited, and considerably smaller than those of the craftsmen and unskilled labour of older techniques, which is itself a consideration, but those numbers must come from a very limited supply in most developing countries. The cost of installing high technology currently includes a very high proportion of foreign exchange. This is unlikely to change in the foreseeable future.

28. Great strides have been made in development of the packaging of electronics to protect systems from outside climate and conditions. Nevertheless the generally tropical climate of Africa with extremes of humidity from damp to dust is hard on electronic based systems. Mechanisms such as tape drives and connectors, essential for portability, cannot be wholly protected. DOS/OSD experience with Doppler equipment suggests that repair and maintenance will be needed and that this is both time consuming and expensive, again with a bias to foreign exchange costs, unless facilities are made available reasonably close to, and accessible from, working areas.

29. More conventional survey equipment, of course, also needs repair and maintenance and many of the factors affecting satellite receivers apply equally to the EDM without which it is now hardly possible to conceive of a survey operation, whether it be for framework or for lower order work. Lack of use, perhaps ironically, can be as big a source of electrical problems, and of the development of fungus on optics, as exposure through operation. Equipment kept in reserve must be very carefully kept if it is not to be found unserviceable when brought out for use.

READJUSTMENT?

30. To carry out a readjustment of the East African framework will cost a considerable sum. It will not be of maximum benefit to Africa as a whole unless it is part of a wider readjustment of most, if not all, of the frameworks of at least East, Central and Southern Africa. (There are already datum discontinuities on the edges of this region). It is unlikely that this cost can be justified as a contribution to economic development, except in isolated areas, because the existing coordinates, despite their shortcomings, are adequate to control mapping and lower order surveys. If funds are to be forthcoming, a possible justification may be on scientific grounds, especially in a new evaluation of the geoid in Africa.

31. The present loss of survey beacons of the existing framework must cause expense through repetition of the work. To avoid further waste of the investment better publicity and explanation of the purpose of the marks, together with funding of regular programmes for inspection and maintenance, are essential. If losses continue at a high rate, a readjustment may not be justifiable as there is little meaning to accurate coordinates of unidentifiable points.

32. Once a high proportion of beacons of the old framework surveys have been lost, the availability of satellite fixations, to provide coordinates of any point virtually on demand may be seen as an alternative to conventional breakdown from framework surveys making readjustment irrelevant. A switch from conventional surveys wholly to satellite fixation is not now inconceivable but it would raise issues which are not currently clear cut. These issues need discussion and resolution as part of any justification of funding for major readjustment programmes.

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